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Laterality effects in the haptic horizontal-vertical illusion

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The tactile horizontal-vertical illusion was studied as a function of hand, size, and figure (L or inverted T). Independent groups of subjects examined raised-line L and inverted T shapes with their left or right thumbs. The illusion varied with stimulus size and the nature of the figure—that is, with whether the pattern was an inverted T or an L shape. No illusion appeared for the L configuration. Furthermore, the strength of the illusion was linked to stimulus size, with the illusion appearing for larger inverted T patterns. The illusion vanished when the left thumb was used for haptic examination. Illusory judgments were only present for the right thumb, implicating the superiority of the right hemisphere for spatial processing.

Tactile illusions have been studied extensively (Craig, 1931; Day, 1990; Day & Avery, 1970; Fry, 1975; Over, 1967, 1968), with considerable interest devoted to the horizontal-vertical illusion. Researchers report that the vertical member of an inverted T is judged as longer than the horizontal member in both vision and touch (see Appelle, 1991; Over, 1968; but also see Hatwell, 1960).

Day and Wong (1971) explained the horizontal-vertical illusion in terms of radial-tangential scanning effects. These effects involve judging movements toward the body as longer than other movements. The illusion can be eliminated by deleting radial motions (Day & Avery, 1970), allowing for an explanation of the illusion in terms of bisection. The bisected element of the T figure is perceived as shorter than the continuous line segment (Tedford & Tudor, 1969). Furthermore, Wong (1977) has proposed that radial motions are executed more slowly, leading subjects to judge them as longer. Moreover, haptic illusions are altered by orientation (Day & Avery, 1970; Day & Wong, 1971).

Recently, Heller and Joyner (1993) found that the horizontal-vertical illusion was influenced by visual experience, with late blind subjects showing a pattern of responses similar to that of the sighted. Sighted subjects did not show the illusion to the L figures; the illusion was only present for larger inverted T figures. The early blind subjects, however, evidenced the illusion to both L and inverted T patterns.

It should be noted that the illusory effects reported by Heller and Joyner (1993) were rather weak in sighted subjects and were clearly dependent on both the size of the figures and visual experience. However, all subjects used their index fingers and were allowed some flexibility in their choice of scanning strategies. This may have meant that some subjects were able to scan smaller stimuli with finger motions, whereas larger stimuli prompted flexion at the wrist or elbow. Consequently, subjects in the present experiment were restricted to the use of their thumbs for the examination of raised-line figures. The use of the thumb was intended to minimize variability in the choice of scanning strategies and promote motions of the whole arm.

Some researchers have proposed that haptic illusions may be influenced by cerebral asymmetries. Lucca, Dellantonio, and Riggio (1986) reported a tactile Poggendorff illusion and a different pattern of responses for the left and right hands. It was interesting that they found greater distortion in the right hand, as well as stronger illusory effects. They interpreted this as consistent with the idea that the right hemisphere subserves visuospatial functions. Heller and Joyner (1993) controlled for the hand variable, instructing half of their subjects to use their left hand for examination of raised-line figures and instructing the other subjects to use their right hand. Unfortunately, this procedure may have obscured any possible laterality effects. We do not have clear evidence on laterality effects in tactual illusions, since Wenderoth and Alais (1990) failed to find any indication of a tactile analog of the Poggendorff illusion.

The present experiment was explicitly designed to examine laterality effects in the tactual horizontal-vertical illusion. On the assumption that the right hemisphere is specialized for spatial functioning, one might expect stronger illusory effects with the use of the right hand.

METHOD

Subjects

There were two groups of right-handed, sighted undergraduate subjects (20 in all: 6 females and 4 males in each group).

Stimuli

The stimuli were produced with a Swedish raised-line drawing kit and a medium-point, black ballpoint pen (see Heller, 1989, 1992a; Heller

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& Joyner, 1993; Heller & Kennedy, 1990). A durable raised line was produced when a medium-width ballpoint pen was pressed and drawn over the textured plastic surface. The thick black line was both tangible and visible (see Heller, 1992a). The four inverted Ts and the four Ls were drawn with equal vertical and horizontal segments of approximately 2.54, 5.08, 7.62, and 10.16 cm.

Design and Procedure

The experiment was a mixed-factor, four-way analysis of variance (ANOVA), with the independent factor of hand (left vs. right thumb) and repeated measures on figure (L or inverted T), size, and judgments of horizontal versus vertical line segments. All subjects were blindfolded throughout. Half of the subjects began with the T figures, and half began with the L, but size was randomized. The subjects were instructed to feel the figures (at the body midline) with the thumb of one hand (the left or right). They were told they could feel the model raised-line drawings any way they wished, but they were prevented from using "measuring" with a pincers posture of the index finger and thumb. Subsequently, the subjects engaged in size estimation by using a pincers posture of the other hand—that is, the hand that was prevented from touching the figures (see Heller & Joyner, 1993, for further details). The subjects were asked to feel the model until they had a good idea of its size and configuration, and then were asked to estimate the size of the top or bottom of each figure. Time limits were not imposed, and the subjects were able to examine the standard stimuli for as long as they desired. The stimuli were placed flat on a horizontal tabletop.

RESULTS AND DISCUSSION

The results showed a complex relationship between the presence of the horizontal-vertical illusion and hand (see Table 1). A mixed-factor ANOVA indicated significant main effects of size [$F(3,27) = 144.3, p < .001$] and illusory horizontal versus vertical judgments [$F(1,9) = 5.2$, $p < .05$]. However, there were significant interactions between size and the illusion, and between figure and the illusion, with a significant three-factor interaction between hand, figure, and the illusion (all ps $< .025$). Thus, the presence of the illusion was dependent on the inverted T figure, a result that implicates bisection.[1]

The interaction between hand and the presence of the horizontal-vertical illusion suggests a further interpretation in terms of laterality effects. An additional pair of repeated measures analyses were conducted on the data for the independent groups using the left or right thumbs. No illusion appeared for the left thumb ($F < 1$), and the only significant main effect was for size of the patterns [$F(3,27) = 93.6, p < .001$]. None of the interactions was significant (all ps $> .10$). A separate repeated measures analysis on the data for the right thumb showed significant main effects of size [$F(3,27) = 69.1, p < .001$] and a significant effect of horizontal versus vertical (illusory) judgments [$F(1,9) = 6.4$, $p = .03$]. In addition, there were significant interactions between horizontal versus vertical judgments and figure ($p < .01$), and a significant three-factor interaction between figure, size, and horizontal versus vertical judgments [$F(3,27) = 3.2$, $p < .05$]. The illusion was only present for the right thumb and the inverted T figure, and was also dependent on size (see Table 1). There was no indication of an illusion for the smallest patterns (see Hatwell, 1960).

The present data (derived from exploration with the thumb) provide little support for the possible influence of radial-tangential scanning effects as the primary basis for the horizontal-vertical illusion.[2] The illusion did not appear in the L figure, despite the presence of radial motions for the vertical segments of these figures. This conclusion is supported by the significant interaction between figure and the presence of the illusion, and the significant three-factor interaction between figure, horizontal-versus-vertical judgments, and hand.

It was interesting that a few of the subjects in this experiment reported a curious illusory effect. They expressed surprise when allowed to see the raised-line stimuli upon completion of the experiment. These subjects said that they thought the L was curved, somewhat like a crescent. The curvature illusion may have derived from a sensory aftereffect induced by repeated tracing of the lines.

The horizontal-vertical illusion was dependent on the use of the right hand. This means that we should not be too quick to discard the notion of haptics as a "reality sense." Illusions may occur in haptics, but it is possible that their presence may be most obvious for nonoptimal exploratory conditions (see Heller, 1992b). If we conceive of accurate haptic perception as dependent on skilled exploration, it is not unreasonable to expect that clumsy movements might magnify perceptual error (see Wenderoth & Alais, 1990). Similarly, the use of the right hand may not always represent an optimal strategy. There is considerable evidence that some spatial tasks are aided by the use of the left hand and by maximal involvement of the right hemisphere (see Heller, 1986; Heller, Rogers,

Table 1
Effect of Size on Mean Estimates (in Centimeters) of Horizontal and Vertical Segments of the L and Inverted T Patterns for the Left and Right Thumbs

	Judged Size							
	Left Thumb/L Stimulus		Left Thumb/Inverted T		Right Thumb/L Stimulus		Right Thumb/Inverted T	
Actual Size	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
2.5	4.7	3.9	4.3	4.3	3.9	3.8	3.8	4.0
5.1	7.2	7.4	6.3	6.9	7.0	7.3	6.4	7.2
7.6	9.8	9.4	9.5	9.7	10.1	9.3	9.3	11.1
10.2	11.0	11.7	11.5	12.0	12.1	12.4	10.4	12.6
Overall	8.2	8.1	7.9	8.2	8.3	8.2	7.5	8.7

& Perry, 1990; also see O'Boyle, Van Wyhe-Lawler, & Miller, 1987).

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NOTES

1. Size estimates in the present experiment are roughly comparable to those previously reported for the index finger (see Heller & Joyner, 1993, Table 1). However, the size judgments for the index finger and the inverted T figure were somewhat smaller than those found for the thumb in the present experiment. It is difficult to explain this in terms of either finger size or cortical projection area, since this pattern was not obtained for the L figure. One possibility is that the thumb, compared with the index finger, is relatively insensitive to bisection cues in the inverted T.

2. A second experiment was conducted to test for laterality effects with the use of the left or right pinky for tactual examination. Ten right-handed subjects (3 males and 7 females) used the left pinky to feel L and inverted T patterns, while another 10 right-handed people (2 males and 8 females) used the right pinky. This experiment yielded highly significant effects of size [$F(3,54) = 269.7, p < .001$], horizontal versus vertical illusory judgments [$F(1,18) = 15.6, p < .001$], and a significant interaction between size and the illusion [$F(3,54) = 7.7, p < .001$]. As in prior research, the illusion was obvious for the larger patterns. None of the other main effects or interactions approached significance. Thus, the illusion was present overall, and verticals were judged as longer than horizontals for both the L and T figures. Use of the pinky magnified the size judgments, with the verticals judged as 9.5 cm and the horizontals estimated at 8.6 cm, averaged over all of the conditions (see Table 1 for data derived from the thumbs). The lack of a laterality effect, and the presence of the illusion for the L figure, would be consistent with an explanation implicating the influence of radial-tangential scanning effects. The pinky is clearly poor at haptic exploration, and its use magnified illusory effects.

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